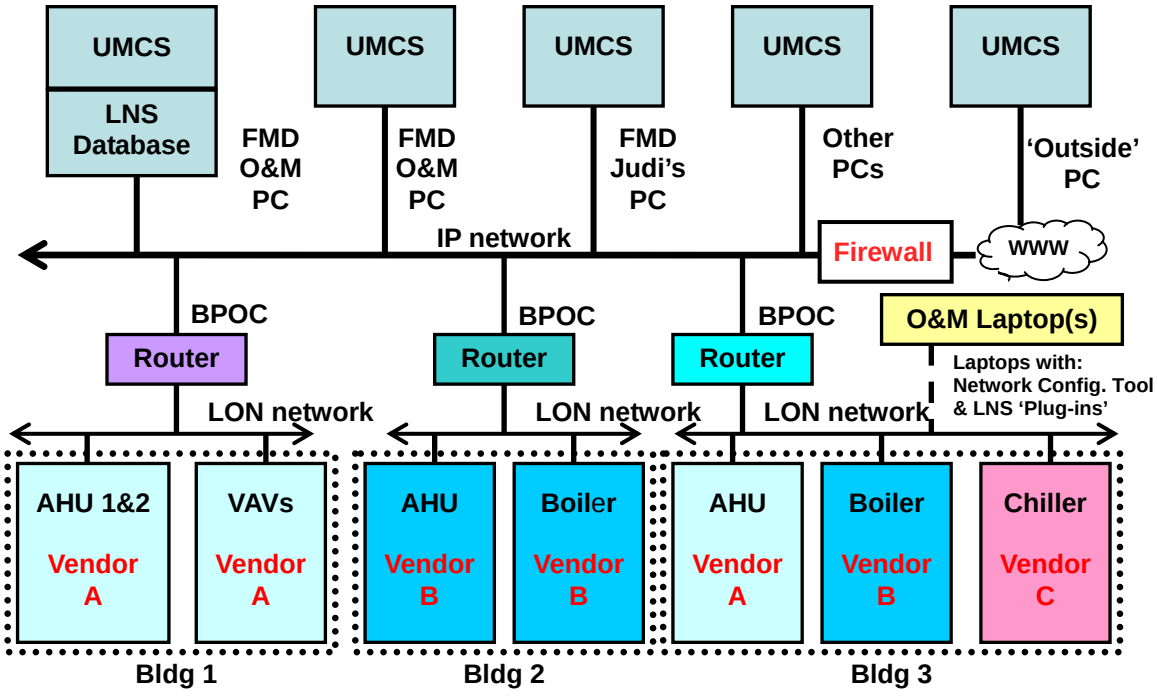
ERDC/CERL TR-05-14

US Army Corps of Engineers®
Engineer Research and Development Center

Heating, Ventilating, and Air-Conditioning (HVAC) Control Systems Operations and Maintenance at Fort Bragg, NC

Training and Technical Assistance

David M. Schwenk, Joseph Bush, and David M. Underwood August 2005



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Heating, Ventilating, and Air-Conditioning (HVAC) Control Systems Operations and Maintenance at Fort Bragg, NC: Training and Technical Assistance

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Final Report

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ABSTRACT: Fort Bragg DPW Facility Maintenance Division Chief requested the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) to provide the installation with site-specific heating, ventilating, and air conditioning (HVAC) systems and controls training and technical assistance. CERL and installation Directorate of Public Works (DPW) management and maintenance staff worked together to identify maintenance issues, training needs, and required resources. This work determined that installation personnel could benefit from three training courses, which CERL developed and provided: (1) Introduction to HVAC and Control Systems Operations and Maintenance (O&M), (2) Advanced HVAC Control Systems O&M I, and (3) Advanced HVAC Control Systems O&M II. CERL also worked with Fort Bragg to identify a direct digital control (DDC) O&M management plan and provided recommendations on how to resolve other ongoing O&M problems.

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Conversion Factors

Non-SI* units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic inches	0.00001638706	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(5/9) x (°F – 32)	degrees Celsius
degrees Fahrenheit	(5/9) x (°F – 32) + 273.15.	kelvins
feet	0.3048	meters
gallons (U.S. liquid)	0.003785412	cubic meters
horsepower (550 ft-lb force per second)	745.6999	watts
inches	0.0254	meters
kips per square foot	47.88026	kilopascals
kips per square inch	6.894757	megapascals
miles (U.S. statute)	1.609347	kilometers
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters
square miles	2,589,998	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

*_Système International d'Unités_ ("International System of Measurement"), commonly known as the "metric system."

Preface

This work was conducted for the Fort Bragg Directorate of Public Works (DPW) under Military Interdepartmental Purchase Request (MIPR) No. 5DCRLPK313, "Fort Bragg Training and Technical Assistance." The technical monitors were Judi Hudson and Jason Lyons, Fort Bragg Directorate of Public Works (DPW).

The work was performed by the U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL), Facility Division Energy Branch (CF-E). The CERL Principal Investigator was David Schwenk. Special acknowledgement is given to Judi Hudson (Deputy Director, Fort Bragg DPW) for her dedication to improving the operation, maintenance, and performance of Fort Braggs HVAC systems. Appreciate is owed for the cooperation, participation, and enthusiasm of all of the maintenance staff including Ed Pettengill (EDV) and Mike Church for their time and assistance in preparing for the training. We especially appreciate Steve Dunning's assistance in reviewing training materials, helping to identify training topics, and his assistance in selecting and preparing for our mechanical room visits. Much of the content and recommendations contained in this report are a direct result of operations and maintenance (O&M) staff suggestions and in-class discussion. We also acknowledge Rod Chisholm (Director, Fort Hood DPW) and Richard Strohl (Fort Hood DPW) for their support and contributions to this work, specifically Mr. Strohl's expert technical advice and assistance and his service as a Fort Bragg training course instructor. James Miller, Joseph Bush, and David Schwenk were the Fort Bragg training course instructors from CERL. Dr. Thomas Hartranft is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Gary W. Schanche. The technical editor was William J. Wolfe, Information Technology Laboratory. The associated Technical Director was Gary W. Schanche, CEERD-CV-T. The Acting Director of CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL James R. Rowan, and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

The heating, ventilating, and air conditioning (HVAC) systems at Fort Bragg, NC encompass approximately 4625 buildings, and a total 16.3 million sq ft of floor space. (The average single-floor building size is 60 x 60 ft.) By extrapolation, each of the 20 members of the Fort Bragg HVAC maintenance staff is responsible for approximately 240 buildings. Many of these buildings contain aged and failing HVAC systems and controls, and many of the controls use very old pneumatic-style controllers (Figure 1). At the same time, a number of new construction projects currently in progress are installing digital control systems.

The large number of controls, and the great mix of old and new controls of different types makes HVAC maintenance at Fort Bragg enormously complex. Moreover, the operations and maintenance (O&M) challenges at Fort Bragg are typical of those at most Army Installation. Aging and failing HVAC systems and controls, constructed with varied and complex technologies, are being repaired, replaced, or augmented with new or retrofit systems.

Figure 1. Antiquated pneumatic style controls are abundant at Fort Bragg.

Most new construction and renovation projects include direct digital control (DDC) technology to provide environmental control of the HVAC systems. DDC includes microprocessor based devices often networked together on a local communications bus. This networking of devices provides an infrastructure that supports various capabilities including O&M activities. Most notably is the capability to directly connect ("jack-in") a laptop computer by cable to the network to perform control system diagnostics and adjustment of controller settings such as set points.

Networked DDC systems are also intended to provide the capability to perform remote supervisory monitoring and control functions, usually installation-wide. These functions might include remote alarm reporting, scheduling (on/off control), trending and trend reports, load shedding/load management, remote setpoint adjustment, maintenance management functions such as initial/basic diagnosis of service calls, and other functions such as utility-monitoring/measurement for the purpose of Energy Savings Performance Contract (ESPC) contract administration. Supervisory monitoring and control of multi-vendor DDC systems through a common interface can only occur when the various building-level systems can inter-communicate.

The most important DDC system O&M tool is a laptop computer with DDC software and a network interface device that connects the laptop to the network bus. The contractor for each construction project usually provides this equipment. Unfortunately, the software and cables provided by one contractor rarely work with the system provided by another. As a result Fort Bragg has a large inventory of laptops (Figure 2) configured with dedicated (incompatible) software packages and network interface devices. Fort Bragg maintenance staff must maintain and be proficient with many different hardware and software systems. This project was undertaken to provide training and technical assistance help Fort Bragg staff improve the O&M of the installation's HVAC systems and controls.

Figure 2. Fort Bragg's 12 O&M laptops (and counting).

Objective

The objective of this project was to provide training and technical assistance to Fort Bragg O&M personnel and to make recommendations to improve the installation's HVAC systems and controls.

Approach

The Fort Bragg DPW Facility Maintenance Division Chief, requested ERDC-CERL assistance, primarily O&M training, to help with their HVAC control systems O&M challenge. This included several initial telephone conversations with maintenance staff, followed by a site visit including meetings and interviews with DPW Facilities Maintenance Division (FMD) management and maintenance staff, visits to about 20 mechanical rooms, and a meeting with the Corps of Engineers Area Engineer and Resident Engineer. These interactions resulted in identification of a need for:

1. *HVAC Systems/Controls O&M Training*. Development and presentation of the HVAC systems and controls training (three site-specific courses) was the primary focus of the project.
2. *DDC O&M Management Plan*. CERL developed this item (and items 3 and 4) as part of the training.
3. *Building Acceptance Checklist*. The need for this checklist was identified during the training courses, so was added to the curriculum of the third training course. This list was developed for DPW use in coordination with Area Office/others.
4. *Installation Design Guide (IDG)* update/refinements.

The third training course also included a 4-hour session attended by Fort Bragg DPW management and mechanics, DOIM, and the Corps District, Area, and Resident offices where items 2 through 4 were discussed in detail.

Mode of Technology Transfer

The results of this work have been furnished to the sponsoring organization. It is anticipated that they will also be incorporated into the existing HVAC Control Systems PROSPECT course training. This report will be made accessible through the World Wide Web (WWW) at URL:

http://www.cecer.army.mil

2 Training

The initial emphasis of this project was to identify and develop training on HVAC systems and controls O&M specific to the needs of Fort Bragg personnel. Researchers determined that three courses would fill this need:

- *Introduction to HVAC Systems and Controls O&M* (2-day course)
- *Advanced HVAC Controls O&M #1* (1 week of half-day sessions, 20 hours)
- *Advanced HVAC Controls O&M #2* (1 week of half-day sessions, 20 hours).

Appendix A includes the schedule of instruction including basic content for each of the training courses. Instructors encouraged and facilitated open dialog during the training, which gave the them further insight into Fort Bragg O&M staff issues and concerns, and allowed them to tailor the course to the specific needs of the installation staff.

Introduction to HVAC Systems and Controls O&M

The introductory course consisted of a pre-packaged course, amended to meet some Fort Bragg specific needs/interests. While much of this course material was relatively old, it was still pertinent and contained good fundamental content. Still, some course information was no longer current (e.g., the "Refrigerant Handling/Maintenance" data and information was about 10 years old; the presentation materials consisted of black-and-white transparencies). CERL researchers supplemented the course with some color photos and illustrations projected using an LCD projector, and updated the refrigerant maintenance data.

Advanced HVAC Controls O&M #1

This course focused on single-loop digital controls (SLDCs) as specified in (the now rescinded) CEGS-15950A since Fort Bragg still has a number of systems with this type of controls. The course included hands-on in-class exercises with a specific vendor's SLDC (TCS Basys SD-1000), and site visits to two mechanical rooms where classroom lecture material was applied.

Advanced HVAC Controls O&M #2

This course included discussion of "generic" DDC systems as specified in (the now rescinded) CEGS-15951A. Since the CEGS-15951A systems are proprietary (not "open"*), instructors used this material as a general foundation for explaining DDC systems rather than focusing on a specific vendor's system. Since the CERL staff has significant hands-on experience with Johnson Controls DDC, the instructors chose to included site visits to mechanical rooms that contained this type of digital controls to apply the in-class lecture material.

The course also included detailed instruction on the new Unified Facility Guide Specification (UFGS) 13801 and 15951 (open system specs) with a strong O&M and construction inspection slant. Acceptable vendor specific LonWorks® compliant control hardware and software was discussed along with an in-class demonstration of a Network Configuration software tool. This course also presented and discussed DDC O&M management, building acceptance procedures, and IDG issues, most notably the use of variable air volume (VAV) systems versus multizone systems.

Training Course Evaluations and Test Results

The training courses were open to both Fort Bragg DPW and Corps Area/Resident office personnel. Most of the students were from the DPW Facilities Maintenance Division (FMD) shop where a cross section of skill levels attended the training including A/C mechanics, electricians, and plumbers. The chief of O&M made it clear to all attendees that they could drop out at any point should the material become too complex, or if they felt they were no longer getting anything out of the training. (Only one or two students dropped out.)

On the last day of the third course, training evaluation forms were distributed to all students. (Appendix A summarizes the results, including students' comments.) Results showed that the courses were exceptionally well received. On a scale of 1 to 5, with 5 as the highest rating, the overall average rating for the 14 different evaluation categories was 4.7. Of particular interest are the following categories and the class averaged responses:

* An "open" system is one for which (hardware and software) components may be acquired from multiple sources. Open systems are more easily modified than proprietary systems because components and service are available and from many sources in addition to the original installer.

	Class Average Rating
The training will improve my job performance:	4.7
My expectations were met:	4.8
I would recommend the course to others:	4.8

On the last day of the third training course, a post-test was administered to help gauge the effectiveness of the course. The average score on the post-test was 13/20; several students scored as high as 19. Considering the wide cross-section of experience in the course including students who have never before received any controls training, these are excellent results. Instructors noted that the post-test scores were comparable to those registered by students of the Corps of Engineers' Proponent Sponsored Engineer Corps Training (PROSPECT) HVAC course (which is intended for individuals performing HVAC control system operation and maintenance, and which the course instructors also teach).*

Future Training

Training is crucial to job performance whether it is conducted in a formal classroom or on the job. In particular, operation of microprocessor-based controls including DDC hardware and software requires a skill set that can only be maintained through recurrent training. Recognizing this, the Chief of O&M expressed her desire to institute an ongoing training program. CERL's recommendations for future training include, in priority order:

1. *Vendor-Specific DDC Training.* Most construction contracts, specifically those that originate at the Corps District level, include contractor-provided training requirements. Fort Bragg should require and enforce training contained in any contract specification. Much of the content and activity that CERL presented in the Advanced Level 1 and Level 2 training course mechanical room visits is similar to what contractors should include as part of the formal training ordinarily required by the construction project contract specifications. This was discussed and reviewed during the Advanced Level 2 training course, and the students were directed to the portions of the specifications that define training requirements. O&M staff awareness of the contract requirements should help to ensure that contractors adhere to the requirements. It is specifically recommended that:

* Further information on PROSPECT Course 72HOM01A (Control No. 246), "HVAC Control Systems: O&M" is available through URL: http://pdsc.usace.army.mil/CourseListDetails1.asp?Cntrl_Num=246

- O&M staff review training requirements/specs during the design phase
- FMD request a copy of the Contract specification training requirements prior to the training date
- FMD take a copy of the Contract specification training requirements to the training.

2. *Vendor Specific Utility Monitoring and Control System (UMCS) Training.* The UMCS front-end Monitoring and Control Software section of this report indicates that certain O&M staff members should receive training on the UMCS software, once it is selected. This would initially be done as a requirement in the UMCS procurement contract where the installing contractor provides on-site training on the UMCS, but additional training is recommended. Nearly all UMCS/DDC vendors offer formal training at "the factory." After a UMCS software package has been selected and installed, Fort Bragg should send one or two O&M staff members to this formal training.
3. *PROSPECT Course 35HQV01A (Control No. 382) "HVAC Control Systems: Quality Verification."*[*] This course provides instruction on LonWorks controls and is pertinent to both quality verification and O&M staff. It provides instruction on HVAC control systems and provides detailed instruction on fundamental LonWorks technology (beyond that presented by CERL in the Fort Bragg "Advanced 2" training course). It also includes a site visit to the CERL laboratory for demonstrations of DDC controllers, DDC VAV box controls, and controller tuning. Fort Bragg should send at least one O&M staff member to this training.
4. *PROSPECT Course 72HOM01A (Control No. 246) "HVAC Control Systems: O&M."* This course is very similar to the "Advanced 1" training course presented to Fort Bragg. The course provides instruction on generic HVAC control systems O&M, but also includes hands-on exercises using single-loop digital controls. Fort Bragg may choose to send O&M staff to this training particularly for those who might need refresher training or those who did not participate in the Fort Bragg Advanced 1 training course presented by CERL.
5. *FMD Staff In-House Seminars.* Fort Bragg maintenance personnel have skills and experiences (some of them exceptional) that would benefit other maintenance staff members. We recommend that each FMD O&M staff member periodically be tasked with making a short presentation to the rest of the staff on a topic of their choosing. Presenters might choose to perform a review of one or more topics from the courses presented by CERL where one staff member (otherwise referred to as the instructor) serves as a moderator to facilitate discussion

[*] Detailed information on PROSPECT Course 35HQV01A (Control No. 382), "HVAC CONTROL SYSTEMS: QV" is available through URL: http://pdsc.usace.army.mil/CourseListDetails1.asp?Cntrl_Num=382

on the presented topic. Fort Bragg should consider inviting former/retired FMD staff in to offer presentations on various topics. These skills and experiences would also be of interest to others outside Fort Bragg. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) meetings are an excellent opportunity for disseminating this type of information. It is recommended that CERL and Fort Bragg work together to develop presentations for ASHRAE.

6. *DDC Vendor Seminars*. Discussions with some of the FMD O&M staff indicate that at least one of the contractors who has installed HVAC control systems at Fort Bragg has offered to provide on-site assistance, possibly without charge. It is recommended that a DPW/FMD staff member investigate the possibility of on-site DDC vendor seminars. CERL researchers have coordinated such seminars in the past, and recommend that an FMD staff member review the vendor's proposed presentation prior to the seminar, specifically to coordinate the content of the presentation with the vendor so that it emphasizes technical content (and minimizes the sales pitch).

3 DDC O&M Management Plan

Background

DDC systems are routinely designed and procured on a building-by-building or subsystem-by-subsystem basis. Inconsistencies and incompatibilities between new and existing DDC systems result in inefficient, complex, non-functioning systems. This is mainly due to the inability of different vendors' DDC systems to interoperate, particularly in base-wide applications. This inability to interoperate is a result of closed (not "open") systems due to vendor-specific proprietary elements.

Two new specifications were released this past year based on ANSI/EIA 709.1 communications protocol including the use of LonWorks® technology consisting of various tools and devices available from a wide variety of manufacturers. The new specifications are: UFGS-13801 (*Utility Monitoring and Control Systems* [August 2004]) and UFGS-15951 (*Direct Digital Controls for HVAC and other Local Building Systems* [May 2005]).* The specifications are designed to be used together—UFGS-15951 is for building-level control systems and UFGS-13801 is for integration of the building level systems with a base-wide UMCS. While the focus of UFGS-15951 is on HVAC control systems, the specifications contain the foundation for other monitoring and control applications, such as lighting control and power monitoring.

The recommended approach for implementing the new specifications is to include a UMCS (as specified in UFGS-13801) in the initial project, which may include one or more building-level DDC systems (as specified in UFGS-15951). The initial UMCS will result in one or more front-end workstations and will establish the LonWorks network database, which can be expanded for future projects. Subsequent building-level DDC systems can be specified to interface with the UMCS using the ANSI/EIA 709.1 communications protocol and ANSI/EIA 852 protocol (ANSI/EIA 709.1 over IP). This technology precludes the need for a building prep specification for UMCS. Note that the front-end software will likely have proprietary elements, but any

* Full text of UFGS-15951 is available through URL: http://www.ccb.org/docs/ufgshome/UFGSToc.htm

building- level system from any vendor, when supplied as specified, will be able to interface with it. Due to the underlying LonWorks network database standard specified in UFGS-13801 and 15951, a new vendor can replace the front-end without replacing the database should the need arise. Figures 3 and 4 show the UMCS/ DDC system.

Benefits to Fort Bragg

The proposed UMCS/DDC Open System approach offers several benefits:

1. *Integrated Systems.* Use of UFGS-15951 (building-level controls) and UFGS-13801 (UMCS front-end) will provide Fort Bragg with a capability to better manage its facilities/buildings. The UMCS supports remote Monitoring Capabilities, including viewing building-level points/data, adjusting control settings, alarm monitoring/handling/routing, and the capability to schedule equipment on/off, which offers advanced features such as load shedding for energy management.
2. *Multi-Technology Support.* Due to the underlying ANSI/EIA 709.1 standard network communications protocol, the UFGSs provide infrastructure and support for technologies other than HVAC such as lighting control, energy monitoring/metering, security/access control. This allows a variety of HVAC and non-HVAC digital control systems to be integrated for monitoring and control.
3. *Single Network Configuration Tool (Software).* The underlying ANSI/EIA 709.1 communications protocol also provides the potential for use of a single Network Configuration Tool. DDC vendors require the use of software tools to set up and configure their networked DDC systems. This is often done using a proprietary and largely system-specific software package. The new UFGSs provide for the use of a single multi-vendor compatible tool to perform network management functions. The UFGSs specify a network tool that uses LonWorks Network Services (LNS™), a de-facto standard for network management of a LonWorks system. The use of a standard LNS-based tool will help to make O&M staff more effective (in diagnostics/repair) and should minimize training needs over the long term since there will be less software for the staff to learn.
4. *Standard Network Interface.* The new specs require use of a standard communications media based on ANSI/EIA 709.3. This simplifies the selection of replacement controllers, since the same controller can be used in multiple systems. In addition, this provides for a common building-level network communications media that allows maintenance staff to connect directly ("jack-in") to the network using a common interface card and cable. This common cable, along with the single "Network Configuration Tool," will help to simplify the use and management of the O&M laptops.

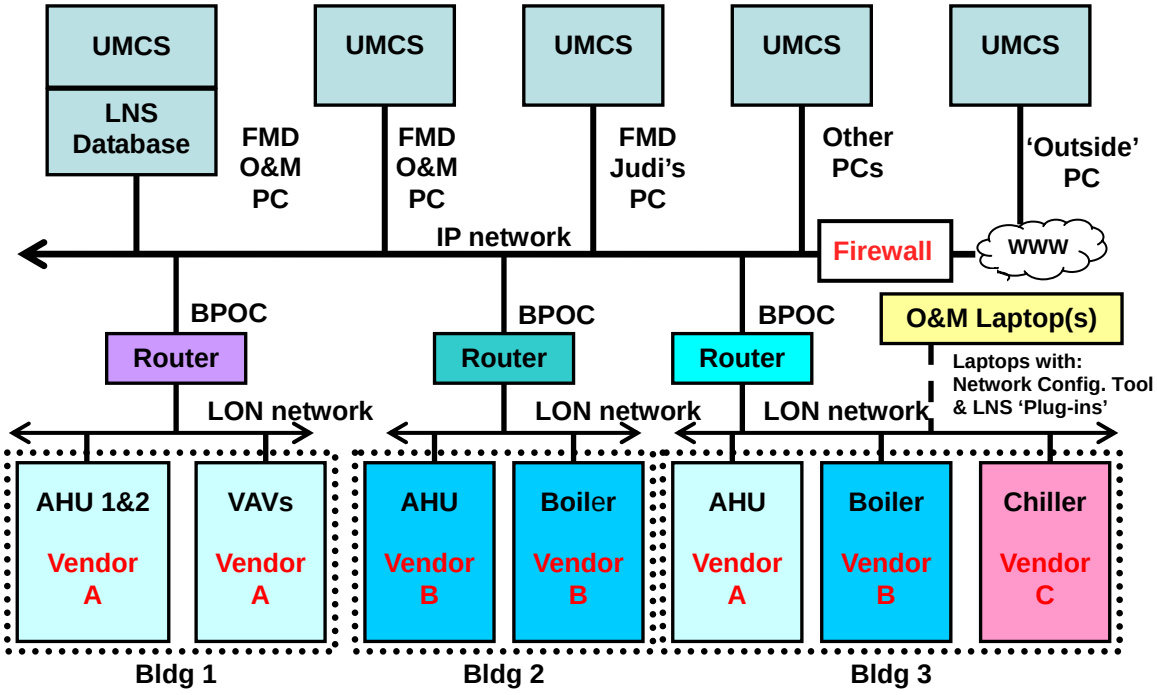

Figure 3. UMCS/DDC open system – functional representation.

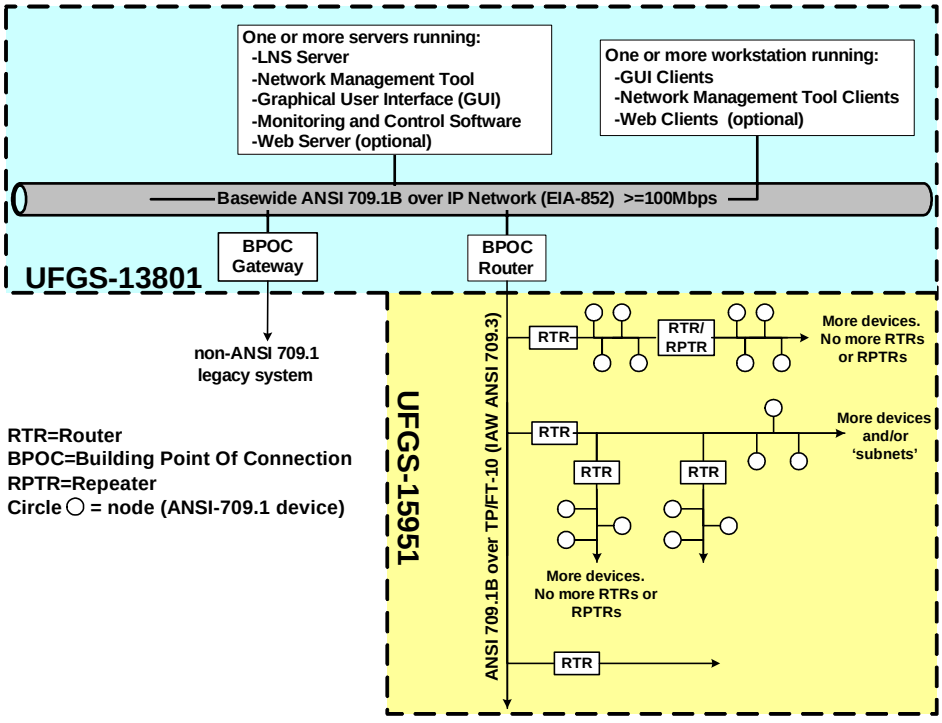

Figure 4. UMCS/DDC open system – technical illustration.

5. *Fewer Software Packages.* LonWorks Network Services (LNS) plug-ins that are used to configure application specific controllers (ASCs) should further help to simplify the use and management of the O&M laptops because of the relatively simple/straightforward requirements/use of LNS plug-ins compared to typical DDC software packages. The use of plug-ins still involves a degree of complexity, but is still simpler than learning software packages from multiple vendors.
6. *Less Hardware.* The use of the ANSI 709.1 protocol along with the associated LonWorks technology as specified in the UFGSs supports the Government's open competition procurements rules, but will likely limit the mix and variations of installed DDC systems because not every DDC manufacturer offers ANSI 709.1 compatible controls. This reduction in variety should help the O&M staff become more proficient. Since the installed systems will be open, however, the O&M staff will have more choice and options in replacing substandard controls with compatible replacement devices (due to standard building control network). These specifications will limit the total number of competitors, but will increase the overall competition (by not being "locked in" to a single vendor) and by providing more choice in replacing control hardware and related management tools.

Implementation Overview

The basic elements required to implement a DDC O&M management plan consisting of a LonWorks UMCS along with building-level DDC systems (shown in Figures 3 and 4 [p 11]) are listed here with each further described in the following subsections:

- Select, define, and document a strategy (including coordination with DOIM).
- Find a System Integrator (SI) to manage front-end (multiple year agreement such as an Indefinite Delivery/Indefinite Quantity [IDIQ]).
- Obtain a LonWorks® UMCS front-end software package through the System Integrator and in accordance with UFGS-13801.
- Obtain an LNS™ Network Configuration Tool (software) through the System Integrator and in accordance with UFGS-13801.
- Require LonWorks controls for all building-level projects installed in accordance with UFGS-15951.
- Identify contractors/products that meet UFGS-15951 and UFGS-13801 LonWorks® requirements.
- Define in-house (Government) support mechanisms/strategy.
- Establish a schedule.

Select, Define, and Document a Strategy

CERL recommended and defined the fundamental elements of a DDC O&M management plan during a 4-hour strategy session with the Corps District Office, Area Office, DOIM, and DPW management staff and maintenance mechanics.

Coordination with the DOIM is important because the proposed system requires a high speed Internet/Ethernet backbone that is interfaced to the building-level control network using EIA-852 routers. This plan, along with any specification that includes Internet/Ethernet requirements, should be coordinated with the DOIM early in the design process to ensure compliance with their requirements. The DOIM will likely be interested in reviewing the UFGS-15951 and 13801 guide specification requirements and may have specific recommendations for additional (or different) contract specification verbiage, particularly for the bracketed specification requirements (that are accompanied by designer notes in the specs).

In-house (Government) support mechanisms along with an implementation strategy need to be identified. This includes defining O&M staff DDC/LonWorks support structure/responsibilities:

1. The DPW needs to manage the LNS database and LNS plug-ins.
2. The DPW needs a strategy, along with a person or persons, to manage the laptop computers and software used for control system O&M.
3. Identify training needs. (Refer to the "Training" section of this report [p 4].)
4. Identify control system acceptance procedures. This report contains a "Building Acceptance Checklist" (p 44) that defines an approach for accepting control systems.
5. Define UMCS Integration procedures. New LonWorks buildings will need to be integrated into the UMCS front-end. The System Integrator will bear much of the responsibility for UMCS set-up and maintenance. These procedures and responsibilities need to be defined. For example, each building-level project will result in a LNS database submittal from the contractor, and this database must be integrated/combined with the master LNS database. The different approaches to performing this integration will all need to be considered case-by-case.
6. Define UMCS O&M procedures. The System Integrator will bear much of the responsibility for UMCS set-up and maintenance, but the maintenance staff will be the primary users. Responsibilities will need to be clear to avoid confusion and to make sure the system continues to function properly. For example designation of responsibility for the purchase of hardware and software including upgrades and additional licenses, coordination with the DOIM and interactions with other contractors all need to be carefully considered and defined.

7. Develop IDG verbiage in support of control system requirements such as the use of LNS-plug-ins and ASCs, or the requirement to exclude programmable controllers, etc. As such, the existing IDG will require verbiage updates, many of which are contained in the report, but Fort Bragg staff will need to review and contribute to this verbiage as well as continue to update the IDG as needed.
8. Identify additional support mechanisms. Three such support mechanisms are:
   a. Savannah District Directory of Expertise for HVAC Controls
   b. Huntsville Division Mandatory Center of Expertise for UMCS
   c. ERDC-CERL Energy Branch.
9. Appendix B includes Web addresses (URLs) for these organizations (p 41).
10. Identify contractors/products that support LonWorks, adhere to the requirements of the Guide Specifications, and adhere to Fort Bragg's requirements. Fort Bragg should establish a task group (or individual) to identify and assess local contractors' ability to provide adequate support. This task consists of pre-identification of potential contractors and hardware (not pre-selection of a specific contractor or hardware). Of primary concern is building-level controls contractors who can provide LonWorks systems that meet the requirements in UFGS-15951. Much of the work has already been done as part of this project where basic hardware requirements (including manufacturers who can meet these requirements) are described in the section "Require LONWORKS Controls for All Building-Level Projects (p 22)." In addition, a UMCS contractor who can provide a system in accordance with UFGS-13801 will need to be identified. In Fort Bragg's case, this consists of finding a System Integrator as described in more detail in the next section "Find a System Integrator (SI)." A list of potential SIs that service the North Carolina area is included.

Find a System Integrator (SI)

UFGS-13801 and UFGS-15951 are intended to be used together. The UFGS-13801 UMCS front-end system is installed once under a single contract, and a UFGS-15951 building-level system is installed with each new building-level construction project. Each time a building-level system is installed it needs to be "interfaced" to the UMCS front-end. Interfacing, for example, consists of adding graphic displays, points, alarms, scheduling, etc. and integrating/updating the master LNS database to include the building-level database.

System integration functions are performed by a System Integrator (SI). Fort Bragg will need to obtain the services of an experienced SI. This will require defining the SIs responsibilities and developing a Statement of Work/Services. Most of the needed requirements/responsibilities can be extracted from UFGS-13801 and some from UFGS-15951. The recommended approach along with the suggested

verbiage (shown below) will need to be edited to address/identify how and who will pay for the required software and hardware. Key qualifications, tasks, and detailed requirements for the SI, as defined in the Fort Bragg developed statement of work (SOW), should include:

1. SI Qualifications: The System Integrator shall have at least 5 years of HVAC control systems integration experience and shall have been materially involved with the installation of at least three LNS-based LonWorks projects.
2. SI Tasks:
   a. Provide, install, and manage a LonWorks® UMCS front-end monitoring and control (M&C) software package (as further described in the section titled "Obtain LONWORKS® UMCS Front-End M&C Software Package" [p 18]).
   b. Provide, install, and manage [X] copies of a Network Configuration Tool on [X] O&M laptops provided by the Government (as further described under section "Obtain an LNS™ Network Configuration Tool (Software)" [p 20]).
   c. Provide and document integration services including integration of each new LonWorks building control system to the UMCS as specified in UFGS-13801 by updating/merging LNS databases, and adding graphics, points, alarms, scheduling, etc to the UMCS GUI front-end software (as further described under section "Obtain LONWORKS® UMCS Front-End M&C Software Package" (p 18) and "Obtain an LNS™ Network Configuration Tool (Software)" [p 20]) .
   d. Adhere to the LonWorks requirements described in this Report.
3. SI Detailed Requirements:
   a. Integration Services Log. The SI shall create and maintain an Integration Services Log to document any activities or actions that impact the UMCS or DDC systems. The log shall be kept current and include but not be limited to:
      (1) Integration Methodology as described below under paragraph "Integration Methodology."
      (2) Riser Diagram Drawing showing the details and location of servers, workstations, printers and other equipment.
      (3) Points Schedule for each integrated building/system including: the Standard Network Variable Types (SNVTs) (points) displayed by the M&C Software, SNVTs that can be overridden by the M&C Software, SNVT alarm points, SNVT trend points, and Alarm Routing (in coordination with the Alarm Routing Schedule).
      (4) Alarm Routing Schedule drawings that identify and assign priorities, pager telephone numbers, e-mail addresses, and alarms to be printed.
      (5) Demand Limit schedule drawing including system name, load shed priority, and SNVT needed for shut-down or setpoint reset.

(6) Control System Schematics for each building-level control system (the as-built drawings submitted by the 15951 contractor).

b. Integration Specifications. The SI shall provide recommended specification verbiage to the Government for use in new control system projects that will facilitate the SIs responsibilities.

c. Integration Methodology. The SI shall develop an integration methodology for "new" LonWorks buildings. The methodology shall be documented and coordinated with the Government. This shall include a procedure for executing LNS-database transfer from the 15951 contractor to the Government. As part of this the SI will need to determine if the 15951 contractor will be permitted to work from the existing database (generally, the answer "no" is assumed for potential "finger-pointing" reasons). In the event the 15951 contractor creates a new database, the SI will need to determine if it should it be merged with an existing UMCS database or if it should remain separate and start a new one. Note that, in general, multiple databases are OK as long as they all reside on a single server.

d. LNS Database Management. The SI shall manage/update the LNS database(s) as part of each LonWorks construction project and shall perform periodic backup of all LNS database(s).

e. M&C Software Maintenance: The SI shall manage the LonWorks UMCS front-end GUI software package including obtaining M&C Software license upgrades to support new buildings installed under UFGS-15951 and obtaining and installing new M&C clients(hardware and software) as required.

f. Coordinate with DOIM. The SI shall coordinate all networking activities (including proposed purchases) with DOIM. This includes, but is not limited to, ensuring that the M&C Software meets DOIM requirements:

(1) If the M&C server is going to be installed on the base LAN, the SI must coordinate/confirm that the software can handle/support operating system (OS) upgrades such that the M&C software continues to function when Windows is updated (not upgraded to a new version, updated with Microsoft released patches, etc.).

(a) If it is not feasible for the SI to ensure that the M&C software will continue to function with operating system upgrades, the SI will need to have to work out alternatives with DOIM. A possible alternative is to set up a private network using the same media (via VPN).

(b) Firewall off the M&C server machine to only accept traffic from the ANSI-852 routers and M&C clients. Similarly, the clients should only accept traffic from the server. (This eliminates web-based clients.)

(c) See if DOIM has any other ideas they would be happy with, such as a VLAN.

(d) Start running a dedicated network for controls (the expensive route) Check to see if DOIM will cost-share if you run multiple pairs of fiber and let them use some.

g. O&M Laptop Management. The SI shall manage all LonWorks O&M laptop hardware and software including operating system, Network Configuration Tool, and LNS Plug-ins. This management activity will initially include assessing the utility of existing laptops for use/conversion to LonWorks O&M laptop while not compromising the pre-existing capabilities of the laptop. The SI shall define requirements for new/additional laptops and/or Network Configuration Tool licenses as needed and coordinate these requirements with the Government for procurement or inclusion in construction project specifications. The SI shall identify and develop a strategy in coordination with O&M staff recommendations and Shop Supervisor or Work Leader approval that maximizes the utility of the O&M laptops. For example, one maintenance staff member suggested that all project documentation (e.g., as-built drawings, control device datasheets, etc.) be stored on the laptop. The SI shall develop and maintain a record of all O&M Laptops. The record shall include a listing of all HVAC control related software installed on each laptop including the software version number/date and control software package log-ins/passwords. It is recommended that each laptop and laptop case be labeled with an identifier. Laptop management activities shall be conducted in a manner that minimizes interference with O&M maintenance staff access to the laptops.

h. Graphic Displays. The SI shall coordinate the development of UMCS M&C software graphic displays with the users and maintenance staff. This shall include content, penetration scheme, and other functional and aesthetic features. Consistency shall be maintained building-by-building and project-by-project.

i. Training. The SI shall provide periodic on-the-job training to DPW/FMD staff members. The training shall be tailored to the needs of the O&M staff with content based on the requirements described in UFGS-13801. The training shall cover both the UMCS M&C software and the Network Configuration Tool.

SI Procurement

Procurement of system integration services could potentially be obtained by including a "system integration" requirement in each new construction contract whereby the burden is on each contractor to perform the integration him/herself or to hire a system integrator. This approach is not recommended because of the technical difficulty in accomplishing this, the contractual complexities, and the lack of a consis-

tent responsible party. The building-level contractor may not be familiar with the UMCS front-end. There is therefore a strong likelihood that the building-level contractor will corrupt or damage the functionality of the UMCS. Moreover, many SI functions, such as long-term management of hardware/software and the development of a consistent integration approach, are not achievable using this approach.

The preferred procurement approach is to award a contract to a single vendor to serve as an SI for a long term commitment, generally about 5 years. Ordinarily, the best way to accomplish this is through an IDIQ contract, where the Installation might develop this contract or use an existing one such as that available through Huntsville Division. Since, Fort Bragg already has an existing IDIQ (or similar) contract, it should give primary consideration to using their pre-existing mechanism.

SIs Serving North Carolina

Appendix B includes a list of six possible companies, found through an Internet search, that likely can meet Fort Bragg's vendor-independent System Integrator requirements, most notably the LNS requirements (p 38). Each serves North Carolina. The list is not exhaustive, but will minimally provide a reference/starting point for a search. Included in the list are SIs from the Open System Alliance (OSA), sponsored at Echelon's website, which lists "Authorized Network Integrators." Also on the list are "Circon LonWorks Integrators" who can service/support multi-vendor LonWorks systems. A call to Circon's "Customer Service and Inside Sales" at 800.338.1866 yielded two of the LonWorks Integrators listed in Appendix B. One of these is co-listed on the OSA website.

Some companies serve multiple states or regions. Care should be taken, when considering a System Integrator, to ensure that they can provide the expected support. In general it is a good idea to make sure such companies have a local/regional office.

Obtain LONWORKS® UMCS Front-End M&C Software Package

The "front-end" M&C software provides an interface to the building-level control systems as illustrated in Figures 3 and 4 (p 11). This front-end "Operator Work-Station" (OWS) can be installed on multiple personal computers (PCs) or laptops. It includes a Graphical User Interface (GUI) to provide graphic display of building-level points / systems. It can be used to view and override points, monitor/log alarms, capture trend data, schedule equipment on/off, and create/print reports. An OWS also serve as a useful O&M/Management tool to provide remote diagnosis in advance of a service call.

Fort Bragg presently receives front-end software packages with existing construction projects. This is problematic because each package is generally vendor specific, and incompatible with other vendors' DDC systems. Ideally Fort Bragg will have a single-vendor's package that is compatible with any other vendor's building-level control systems. This is the intent of the new LonWorks-based UFGSs.

UFGS-13801 defines requirements for a UMCS front-end M&C software package. Fort Bragg, in coordination with the System Integrator, should base the selection of the UMCS software package on the requirements in UFGS-13801. In addition, Fort Bragg might want identify site specific features, requirements, and capabilities and edit UFGS-13801 accordingly. Some things Fort Bragg, in coordination with the SI, should consider include:

- Demand limiting: This is included in UFGS-13801. Does Fort Bragg need/want this? Will they down the road? Fort Bragg should probably keep the requirement, but maybe simplify it even more to just require that the software have a demand limiting "capability."
- Web-based GUI: This is not explicitly covered in UFGS-13801, but CERL has draft specifications (edits to UFGS-13801) should it be desired. Some considerations are:
  - Does Bragg want/need a web-based GUI?
  - What kind? Either of the following is likely to be suitable at Fort Bragg:
    * "Thick client": requires vendor-specific software on client machine
    * "Thin client": requires standard browser software on client machine.
  - What level of functionality does it need to provide:
    * All the GUI functionality ?
    * A subset of the GUI functionality?
- How many clients/licenses are needed?
- How many points does it need to support? (The number of points shown in UFGS-13801 is probably too low to meet Fort Bragg's needs.)
- Is the "system graphics display" as described in UFGS-13801 what Bragg wants?
  - Does Fort Bragg want "pictures" (as UFGS-13801 specifies) or just a "Windows® Explorer"-type interface?
  - If pictures, does Fort Bragg want "3-d" or "1-line" representation of systems.
  - During the Advanced Training Course #2, FMD maintenance staff indicated that they would like the GUI to display the control device manufacturer name, model, and part number. The SI should investigate this to determine its feasibility and a mechanism for accomplishing this.

UFGS-13801 states that the UMCS M&C software must be "LNS-Compatible." Ideally it will use (only) LNS to interface to the building-level control systems. If

this is not possible with the selected/proposed package, it would be acceptable for the package to use its own internal database provided that it automatically transfers any changes made to one of the databases (LNS or its internal) to the other so that the two are always in agreement.

Training on the new UMCS M&C software should be provided to the O&M maintenance staff who will be using the system.

M&C Software Procurement

The LonWorks UMCS front-end M&C software package can be purchased using a competitive bid approach, as a requirement in a new construction project, or as selected by the System Integrator. Due to the typically long period of time required to obtain the front-end as a requirement in a new construction project, it is usually preferable to procure the UMCS as a separate purchase order (PO). The ideal approach, as appears to be possible at Fort Bragg, is to have the SI install the M&C Software, thus having the SI select the software that he/she is familiar and experienced with. The exact procurement methodology will depend on Fort Bragg's contractual arrangement with the SI. Appendix B includes a listing of acceptable UMCS (software) vendors/suppliers. Note that CERL does not have in-depth/first hand experience with all listed vendors, and has made a judgment based on available information. In addition, the list of vendors is not necessarily complete. A detailed review of the proposed UMCS should be performed prior to selection.

Fort Bragg (in coordination with the SI) will need to decide how many M&C Software licenses (described in UFGS13801) to procure as illustrated in Figures 3 and 4 (such as FMD shop, Chief of O&M, Area Office, CMD, etc., p 11). Once the M&C software is installed, do not require/allow UFGS-15951 project contractors to submit new/different M&C software packages.

Fort Bragg should coordinate the UMCS procurement package with DOIM to ensure that their needs/requirements are met.

Obtain an LNS™ Network Configuration Tool (Software)

An LNS Network Configuration tool is a software package used to manage the LonWorks network and the LNS database. LonWorks Network Services (LNS) is an Open Network Management standard/methodology developed by the Echelon Corporation. It is a de facto standard (many HVAC Vendors use/support it) for the management of LonWorks networks. Also, the guide specs require use of an LNS-

based Network Configuration Tool. This Network Configuration tool will allow FMD personnel to work on the multi-vendor network and the devices connected to the network. In summary, it supports the following functions:

- Install devices (controllers).
- Change settings in the devices (setpoints, PID settings, etc.).
- Troubleshoot:
  - Check/read temperatures, flows, etc.
  - Observe outputs
  - Override inputs.
- Remove or relocate devices.
- "Bind," i.e., establish communication between devices so that devices can exchange data (usually done by the installing contractor).
- Creates and maintains a "map" of the network, where the map is a database/image of the network serving as a record of what the network looks like (devices/controls connected to network). The "front-end" computer(s) also use the map to do supervisory monitoring and to control the network devices.

Some of the above functionality is achieved through use of LNS Plug-ins, as described elsewhere in this report. In short, an LNS-plug-in is software (provided by individual controller/device manufacturers) that is "launched" from the network configuration tool.

The System Integrator will need a copy of the LNS Network Configuration tool software and a copy should be installed on each O&M laptop.

Network Configuration Tool Procurement

Although LNS Network Configuration Tools are available from several vendors, a single vendor's software package should be purchased by competitive bid, or by the System Integrator's selection. Using the same network configuration tool on all O&M laptops simplifies system maintenance and reduces the number of software packages O&M staff must learn. UFGS-13801 defines requirements for an LNS Network Configuration Tool. These requirements should be excerpted from 13801 and used as the basis for the procurement order. It is important that the Tool be LNS-based (not just LNS-compatible), i.e., it must both read and write an LNS database. Software that "exports" an LNS database but cannot open/read an existing LNS database is not acceptable. Note that UFGS-13801 says that the tool has to "solely use LonWorks Network Services (LNS) for all network configuration and management of ANSI/EIA 709.1B devices." This, in essence, defines what is meant by "LNS-based." Appendix B includes a list of acceptable Network Configuration Tools. CERL does not have in-depth/first hand experience with all listed vendors;

the list was compiled based on available information. In addition, the list of vendors is not necessarily complete. A detailed review of the proposed tool should be performed before selection.

The System Integrator, in coordination with Fort Bragg, will need to decide how many software copies (licenses) to procure. Once you have a network tool, do not require/allow contractors to submit new/different network tools (on any new O&M laptop). This will help to ensure consistency in use, help to simplify user training requirements, and help to simplify software maintenance (such as software updates/upgrades).

Fort Bragg should coordinate the Network Configuration Tool procurement package with DOIM to ensure that the installation's needs/requirements are met.

Require LONWORKS Controls for All Building-Level Projects

Fort Bragg is currently receiving LonWorks controls on some of their projects, but not in accordance with the requirements of UFGS-13801 or 15951. As a result, these controls are not compatible and interoperable with other vendors control systems.

UFGS-15951 specifies building-level LonWorks controls where the intent is to obtain multi-vendor compatible and interoperable control systems. Fundamental requirements include a common network media, a single type of network interface jack, a single network configuration tool, and vendor-supplied LNS Plug-ins (software for controller/device configuration) that can be launched from the Network Configuration Tool.

Fort Bragg should require the use of LonWorks controls in accordance with UFGS-15951 for all building-level HVAC projects. Key requirements are that:

1. Designers must use the "Points Schedule" drawings to show LonWorks points and functions. Points Schedules and other LonWorks control drawings are accessible through URL:
   http://www.cecer.army.mil/KD/HVAC/
2. Require an LNS database submittal for every project.
3. Require an LNS "plug-in" submittal for every application specific controller (ASC). An LNS plug-in is software supplied by the controller/device manufacturer (on disk or CDROM, or downloaded over Internet) that is run from (inside of) an LNS Network Configuration Tool. The plug-in is used to configure a controller for its control application (VAV box, air handler, fan coil, etc.) through a

user-friendly interface. An LNS plug-in for a specific controller can be run from a Network Configuration Tool from another vendor to set-up and configure vendor the controller. Not all vendors provide LNS plug-ins, but many do. It is not difficult to develop an LNS plug-in, so Fort Bragg, by requiring plug-ins, can help persuade more vendors to develop plug-ins. Appendix B contains a listing of ASC vendors who provide ASCs with LNS plug-ins. CERL does not have in-depth/first hand experience with all listed vendors and generated this list using available information. In addition, the list is not necessarily complete so a review of the availability of a plug-in for a specific controller or the availability of a controller with a plug-in for a specific application should be performed prior to selection or approval of an ASC. Not all vendors support the LNS plug-in standard. In the event a vendor cannot supply an LNS plug-in, and the government chooses to permit the use of that vendors controller, the contractor must provide a list of all configuration parameters/properties for the controller. This should be done on the "Points Schedule" drawing. This is explained (and required) in the "Points Schedule Instructions" drawing.

4. Require LonMark certification for all ASCs. LonMark-Certified products are designed to be easily integrated, monitored and controlled using any choice of network tool. LonMark-Certified products* have been verified to conform with the LonMark Interoperability Design Guidelines. † Non-certified ASCs should be permitted on an exception basis only and only after review by the COR and upon guarantee from the contractor that the ASC conforms with the LonMark Interoperability Design Guidelines.
5. Additional recommended requirements (beyond those contained in UFGS-15951): There are two basic types of controllers: Application specific controllers (ASCs) and programmable controllers. Programmable controllers require additional software to program the controller for its application and are therefore generally more complex to operate, maintain, and replace than ASCs. Although UFGS-15951 permits the use of programmable controllers, it is recommended that Fort Bragg avoid them whenever possible. This can be accomplished by specifying/requiring that only application-specific controllers (ASC) be used for all projects (think "simple") and therefore permit programmable controllers on an exception basis only. We recommend that programmable controllers only be permitted when the control application is too complex for an ASC. This in turn

* A LonMark certified device listing can be found at URL: http://www.lonmark.org/Products

† The LonMark Interoperability Design Guidelines consist of the "LonMark Application-Layer Interoperability Guidelines" and "LonMark Layer 1-6 Interoperability Guidelines," which can be obtained from the LonMark International website through URL: http://www.lonmark.com

suggests that designers must avoid complicated control sequences that would require programmable controllers. Where a specified sequence is too complicated to be implemented using a given contractor's ASC, the contractor should be permitted and encouraged to submit an alternate control sequence that will work with the contractor's proposed ASC.

Appendix C to this report (p 45) contains recommended verbiage for inclusion in Fort Bragg's IDG.

Appendix B includes a list of acceptable DDC hardware. CERL does not have in-depth/first hand experience with all listed vendors; the list was compiled based on available information. In addition, the list of vendors is not necessarily complete. A detailed review of proposed hardware should be performed prior to selection.

Building Acceptance Checklist

The DPW/FMD and specifically O&M mechanics should actively participate in acceptance of buildings. This should start with an operability review of the system design and specifications. A seemingly logical end point is final acceptance of the constructed building, but FMD and the Corps should consider carrying acceptance through the end of the warranty period. CERL's experience is that installations find it difficult to get contractors to abide by warranty requirements. Required logs are not kept or sometimes do not include useful detail. As a result, upon end-of-warranty turnover, the installation maintenance staff often find it difficult to "catch up" on the maintenance needs of the building. A possible solution is to require a refresher training session at the end of the warranty period where the contractor repeats the training conducted at turn-over and also reviews the maintenance log with the O&M staff. This may not be contractually easy or even possible, but is worth investigating. Fort Bragg might want to consider using O&M funds to pay the installing contractor to return to provide refresher training. Appendix C includes a "Building Acceptance Checklist" (p 44).

4 Variable Air Volume vs. Multizone Systems

Near the end of the Advanced 2 training course, a 4-hour session was held with Fort Bragg DPW management and mechanics, DOIM, and the Corps District, Area, and Resident offices to present and discuss changes to the Fort Bragg *Installation Design Guide (IDG)*. Both the DDC O&M Management Plan and the advantages and disadvantages of VAV and Multizone" systems were discussed. The chapter includes some background on the "VAV vs. Multizone" issue. Appendix D (p 45) includes recommended IDG updates relative to VAV systems along with some other "Mechanical System" recommendations. Appendix D also includes a list of those who attended the 4-hour IDG session.

Executive Order 13123 requires that the Energy Use Intensity (EUI) of Federal buildings be reduced by 35 percent from FY85-FY10, or 1.4 percent /yr. The pending Energy Policy Act 2005 (EPAct2005) calls for even steeper reductions, of 2 percent/yr, to an EUI of 75.4 kBtu/sq ft by 2013. Further, it revises performance standards for new Federal buildings to 30 percent below consumption in ASHRAE Standard 90.1 for commercial buildings, or 30 percent below International Energy Conservation Code (IECC) for new residential buildings. EPAct 2005 also requires following sustainable design principles and using Energy Star or Federal Energy Management Program (FEMP) designated products. As part of the Sustainable Design and Development (SDD) initiative, HQUSACE Engineering Construction Bulletin 2003-20 states that "All MCA and AFH projects are required to use SPiRiT. Starting with the FY06 programs, all vertical projects with climate-controlled buildings are required to achieve a Sustainable Project Rating Tool (SPiRiT) Gold rating."

It is a well established fact that a VAV system can reduce energy consumption compared to a Multizone system, primarily because the use of a variable speed drive can reduce operating costs by 20 to 50 percent. These "calculated" values do not take actual life cycle operation into account. A study by Maisey (2005) indicates that the life cycle cost of a VAV System is actually higher than that of a Multizone when all costs are taken into account. As an example this study analyzed the differences between these two systems for a 200,000 sq ft office building in Philadelphia. Table 1 lists the costs of the two systems.

Table 1. Costs of VAV and multizone systems.

Cost Factor	VAV	Multizone
Productivity Change	-$2.5/sq ft/yr	+$2.5/sq ft/yr
Installation Cost	$1.15/sq ft/yr	$1.10/sq ft/yr
Operation and Maintenance	$1.17/sq ft/yr	$1.12/sq ft/yr
Total Annual Costs	$0.77M/yr	$0.75M/yr

Maisey further supports this analysis by making the following observations:

- VAV boxes and coils are typically hidden in ceilings whereas Multizone systems have all moving parts in plant rooms, so that the Multizone system is easier to maintain.
- VAV boxes have additional fans thus increasing maintenance needs.
- VAV systems are more costly than Multizone when a change in the use of the facility requires system modification.
- Outside air, recirculation, and air movement control are more problematic in VAV systems than Multizone.
- The overall ability to provide comfort control under various load conditions is greater for Multizone.

Another consideration that may further impact VAV System operating cost is commissioning. ASHRAE research project RP 1137 indicates that VAV systems are rarely if ever commissioned to the point required to achieve the maximum energy savings typically cited (Klaczek et al. 2004). One example of this was the operating zone airflow. All three systems examined were operating in excess of design airflow (9.4, 17.6, and 9.2 percent excess). These observations agree with CERL's field experience. A multizone system is easier to maintain than a VAV system due to the comparative ease of problem diagnosis, equipment and control hardware access, and simpler control strategy. This coincides with "The Three Common Sense Laws of Long Term Maintenance" (Maisey 2005):

- Air moving parts must be in plant rooms.
- If it is not easy to maintain; it will not be maintained.
- Maintenance manpower and effort will decrease over time.

A survey of 22 Fort Bragg maintenance staff, when asked which was more maintainable on a scale of 1-10, showed a preference for multizone over VAV by a factor of 2.7 (the total score for one divided by the other). Recognizing that some staff members would have varying degrees of confidence in their ratings due to different levels/degrees of maintenance experience with these systems each staff member was asked to apply a confidence level to their ratings. With these confidence levels factored in, the preference for multizone preference increases to 3.1. Those responsible for the actual maintenance of these systems clearly find multizone systems easier to maintain. The Fort Bragg maintenance staff preference and experience is not

unlike that of the maintenance staffs at other Army installations CERL has visited; maintenance staffs commonly complain about the maintenance access problems and relative complexity of a VAV system as compared to the multizone system.

Use of SPiRiT, as called for in Fort Bragg's IDG, calls for adherence to ASHRAE Standard 90.1, but Std 90.1 does not prohibit the use of a multizone system. Further, real world commissioning, maintenance, and actual operating conditions of VAV and multizone systems within the Army, might indicate that multizone systems actually have a higher SPiRiT rating than VAV.

A report to HQUSACE on transforming military project delivery states:

> (Army) Installations are convinced, and perhaps with good reason, that their annual O&M needs will never be fully funded. Installations have stated that they can only expect to receive 30% of their budget request. This funding situation has driven the Installations to put demands on the Districts to provide facilities with the lowest O&M cost possible, […] in many cases lowering O&M costs beyond what is practical. (Black & Veatch 2005, pp 4-12)

Fort Bragg designers may want to consider another option as a compromise between VAV and multizone systems: a multizone system with a variable frequency drive on the air handler fan motor. The basic idea is to vary airflow based on the zone or zones maximum airflow requirements. This system offers the advantage of potential energy savings, but also has the disadvantage of a more complex control strategy. (CERL has not fully investigated this type of system.)

Practical non-energy considerations and limitations that must be considered when choosing Multizone or VAV Systems are:

- "Humidity control is a potential problem with VAV systems. If humidity is critical, as in certain laboratories, process work, etc., constant-volume airflow may be required" (ASHRAE 2004). Multizone systems can also have difficulty controlling humidity during high outside air humidity conditions. This can be overcome by raising the hot deck temperature setpoint, forcing more air through the cold deck.
- Ensuring that adequate outside air for ventilation is difficult in VAV systems. Where adequate outside air is critical, VAV systems should be avoided.
- Multizone air handlers require a premium of mechanical room space due to the requirement of separate cold deck and hot deck ducting prior to mixing.
- Multizone air handlers require a large number of analog I/O points. This sometimes requires multiple controllers for a single air handler.

- Since multizone systems have all equipment (except thermostats) in a single mechanical room, they can be more easily serviced than a VAV system. This is especially true when the zones are in high security areas in which maintenance personnel may require an escort to the zones.

In cases where a VAV system is installed, the design should incorporate maintenance features listed in Appendix D section, "Fort Bragg IDG Recommendations" of (p 45). These recommendations were identified and developed in coordination with the Fort Bragg maintenance staff during the training phase of this project.

5 Conclusions and Recommendations

Conclusions

The Fort Bragg HVAC maintenance staff is responsible for approximately 240 buildings per staff member. Many of these buildings contain aged and failing HVAC systems and controls, including very old pneumatic-style controllers. Additionally, a number of new construction projects are installing digital control systems. The maintenance staff has found it difficult to maintain a working familiarity with the wide variety of old and new controls. After CERL researchers met with Fort Bragg O&M staff, the Deputy Director, Fort Bragg DPW concluded that installation personnel could benefit from three training courses, which CERL developed and provided: (1) Introduction to HVAC and Control Systems operations and maintenance (O&M), (2) Advanced HVAC Control Systems O&M I, and (3) Advanced HVAC Control Systems O&M II. (This third training course included a 4-hour session attended by Fort Bragg DPW management and mechanics, DOIM, and the Corps District, Area, and Resident offices.)

Interactions with Fort Bragg personnel in these sessions also identified needs for:

1. *DDC O&M Management Plan,* which CERL developed as part of the training.
2. *Building Acceptance Checklist*. This checklist was added to the curriculum of the third training course, for DPW use in coordination with Area Office/others.
3. Update/refinements to Fort Bragg's *Installation Design Guide (IDG).*

Recommendations

As a result of CERL's site visits, training, and O&M staff meetings, it is recommended that Fort Bragg take the following steps:

1. *DDC O&M Management Plan.* Fort Bragg should implement the DDC O&M Management Plan as described in this report (Chapter 3). This plan is a "living document" that defines a strategy for the design, specification, installation, operation, and maintenance of all future DDC systems, including the installation of a UMCS. The primary element of the plan includes use of the new UFGS (specifications) that provide for open, non-proprietary, and interoperable multi-vendor control systems based on LONWORKS technology in accordance with UFGS-13801 (UMCS) and 15951 (DDC). The UMCS consists of a UMCS front-end that can

provide for remote monitoring and supervisory control of the building-level DDC systems from multiple operator workstations (PCs). A key requirement of the plan is locating and procuring a System Integrator to manage and maintain the UMCS and the DDC O&M tools, such as laptop computers.

2. *Building Acceptance Checklist.* Fort Bragg should refine and implement the Building Acceptance Checklist contained in this report. This checklist provides the maintenance division with a methodology that lists specific steps intended to help ensure that buildings are turned over/accepted in operable condition. It begins with an operability review of the design and specification and culminates with FMD participation in final acceptance (most notably the Performance Verification Test of the building's control systems). It is recommended that Fort Bragg circulate the final draft version of the checklist (contained in Appendix C, p 44) among the maintenance staff to solicit input and then coordinate the list with the Corps Area Office and Fort Bragg CMD to obtain their input and to identify an implementation strategy. A copy of the final "generic" list should be courtesy copied to the Corps District Office. For a specific project, the Area Office should initiate the list by routing it to the O&M Chief. The chief initials it and routes it to the appropriate FMD Shop Supervisor and/or Work Leader who is responsible for day-to-day progression of the checklist for the specific construction project. The Area Office should be responsible for notifying FMD of upcoming checklist items that require FMD staff participation.
3. *Training Curriculum.* The initial phase of training consisted of an introductory HVAC systems and controls O&M course and two advanced controls courses. These courses covered much terminology and fundamental HVAC and controls, the steepest part of the learning curve. Follow-on training is recommended.
   a. The most beneficial follow-on training is to participate in contractor supplied training offered as part of most construction contracts. This training, if presented in accordance with the guide specification requirements should include demonstrations of the vendor-specific and building-specific systems and control hardware. It is our belief that once O&M staff speaks the language and has the basic feel for HVAC controls, as was the intent/purpose of the three training courses, "seeing" and experiencing actual systems is the next logical step achieving a higher degree of O&M proficiency.
   b. Because of the unique experiences and qualifications of individual staff members we also recommend periodic in-house seminars where staff members present short training lectures to other staff members.
   c. Some additional formal training is also recommended as described in the body of the report, most notably training on the (future) UMCS front-end software and the Network Configuration Tool.
4. *IDG Updates.* As part of development of the three training courses and as part of in-class discussions during the courses, a list of recommended updates to the IDG

were identified and are listed in Appendix D (p 45). Fort Bragg should consider establishing an IDG working group consisting of maintenance staff personnel. This working group should meet periodically, tentatively once per quarter, to review the Fort Bragg IDG and to suggest updates. A suggested agenda:

a. Review of the current "Mechanical Systems" portion of the IDG
b. Staff experiences with unsatisfactory design practices, installation practices, and equipment
c. Proposed IDG updates including recommended IDG wording/requirements and design/material improvements
d. Follow-up research/investigations.

5. Fort Bragg should act continue to exercise its historical preference for multizone over VAV systems. Although VAV systems (theoretically) use less energy than multizone systems, multizone systems can be shown to have lower Life Cycle Costs than VAV systems, and are much more easily (and consequently more likely to be) properly maintained. If a multizone system is deemed ineffective or inappropriate, and a VAV system is instead specified, it should be installed in accordance with the requirements described in Appendix D, "Fort Bragg IDG Recommendations" (p 45).
6. *Internet Access for FMD Staff.* FMD should consider setting up one or two computers in the common area of the shop for Internet access use by maintenance staff. Useful online O&M resources are abundant. CERL may have suitable PCs available that would otherwise be excessed. A list of useful websites is included in Appendix B (p 41).
7. *Future Work.*
   a. The Energy Conservation Investment Program (ECIP) has historically funded UMCS and UMCS-related projects. A part of future ECIP projects might include renovation of pneumatic control systems (along with other opportunities such as the ball field lighting control suggested by Mr. Sullen). Contingent on funding, Fort Bragg should work with Savannah District (Lucie Hughes) and the CERL Energy Branch to develop one or more ECIP proposals.
   b. Fort Bragg and CERL should work with IMA to leverage Fort Bragg's O&M Training and DDC Management Plan initiatives such that they benefit other installations and continue to benefit Fort Bragg.
   c. Fort Bragg should consider follow-up site visits by CERL. Some maintenance staff indicated that there are some particularly problematic HVAC control systems that they would like assistance with. Fort Bragg might also benefit from additional assistance with the development of the DDC O&M Management plan including possible full development of the SOW for the System Integrator, review of potential SIs, and assessment of the capabilities of local UFGS-15951 contractors including possible meetings with local contractors.

References

ASHRAE, *HVAC Systems and Equipment Handbook* (2004), p 2.10.

Black & Veatch Special Project Corporation, Final Report, *Transforming Military Project Delivery* (April 2005).

Klaczek, W., M.Y. Ackerman, P. Fleming, and B.A. Fleck, "ASHRAE RP 1137: Field Performance Assessment of VAV Control Systems Before and After Commissioning," June 2004.

Maisey, Grahame E., "Total Quality Commissioning," *Whole Building Design Guide* (National Institute of Building Sciences 2005).

Appendix A: Course Materials and Results

Schedules of Instruction For Training

Fort Bragg
HVAC O&M Training
Basic Concepts and Vocabulary
15-16 March 2005
Schedule of Instruction

Tuesday (0730-1600)
Introductions
Course Objectives
Basic Principles of HVAC

1130-1230 Lunch

Maintenance Procedures

Wednesday (0730-1600)
Maintenance Procedures (Cont.)
HVAC Control Systems

1130-1230 Lunch

HVAC Control Systems (Cont.)
Refrigerant Maintenance
Discussion / Q&A
Award certificates

Continued…

Fort Bragg
HVAC Controls O&M Training
Advanced #1
21-25 March 2005
Schedule of Instruction

Note: Students will attend either morning sessions or afternoon sessions (not both).
Group1 sessions are 0730-1130. Group 2 sessions are 1230-1630
Except: Groups 1 and 2 are combined on Friday (0730 -1130).

Monday AM (Group 1) (Monday is optional for more advanced students)
Registration, introductions and optional pre-test
Control systems and loops
Multizone (MZ) system
Variable Air Volume (VAV) system and VAV boxes
HTHW system
Single-loop digital control (SLDC) panel operation and control drawings

Monday PM (Group 2)
Same as above

Tuesday AM (Group 1) FMD PERSONNEL ONLY
Single-loop digital control (SLDC) familiarization (hands-on)
Hands-on in-class labs
Proportional control
Time clock
Reading schematics

Tuesday PM (Group 1) FMD PERSONNEL ONLY
Same as above

Wednesday AM (Group 1)
Control Hardware
EPs, pos. positioners, elec actuators, airflow stations, minOA device, etc.
Tuning PID controllers
SLDC settings: Cooling coil, Heating coil with setpoint reset, Economizer and mixed air temperature, Duct static pressure

Wednesday PM (Group 2)
Same as above

Thursday AM (Group 1) (Meet at Bldg 2-4406 at 0730) FMD PERSONNEL ONLY
Group will be split into two subgroups and spend 2 hours in each building:
– Bldg 2-4406 (MZ and Dom HW SLDC and time clock)
– Bldg 2-4xxx (Same complex as Bldg 2-4406) (VAV & Heating HW SLDC)

Thursday PM (Group 2) (Meet at Bldg 2-4406 at 1230) FMD PERSONNEL ONLY
Same as above

Friday AM 0730 -1130 (Groups 1 and 2)
Generic DDC hardware
Johnson Controls Metasys – architecture, hardware, software
Johnson Controls HVAC Pro/WinPro software
Honeywell Excel – architecture and hardware overview
Award certificates

Fort Bragg
HVAC Controls O&M Training
Advanced #2
11-15 April 2005
Schedule of Instruction

Note: Group1 sessions are 0730-1130. Group 2 sessions are 1230-1630 (except for Friday).

Monday AM (Group 1)
Review of Week 1 SLDC Lab and Prep for Week 2 DDC lab
Hardware (continued from Week 1)
Barber Colman CN 8102-0-1 electronic controller (Outside air reset controller)
Pneumatic controller settings (Johnson Controls and Honeywell)

Monday PM (Group 2)
Same as above

Tuesday AM (Group 1) (Meet at Youth Activities Center - Bldg 4-1431 at 0730)
FMD PERSONNEL ONLY
DDC lab:
– HVAC Pro/WinPro software (AHU and VAV controllers)
– DX-9100

Tuesday PM (Group 2) (Meet at Bldg D 4-1431 at 1230) FMD PERSONNEL ONLY
Same as above

Wednesday AM (Group 1)
LonWorks technology: Concepts, Network architecture, Database, Nodes and node licensing, Computer workstation, Graphical User Interface, Network tool, Plug-ins, Quality verification

Wednesday PM (Group 2)
Same as above

Thursday AM (Group 1) 0730 Overview of LonWorks (including Q&A)
0815 Break
0830 DDC O&M Management Methodology (including Q&A)
0945 Break
1000 MZ versus VAV (IDG issues/needs/requirements)
– Other IDG issues as time allows
– Q&A

Thursday PM (Group 2)
Same topics as above

Friday AM 0800-1200 (Groups 1 and 2)
Review and highlight Advanced Course 1 and 2 material
Open discussion / questions / comments
Course evaluations
Post-test
Award certificates

Training Course Evaluation Results

	Name (Optional)	Attended Introductory Course	Attended Advanced 1	Attended Advanced 2	In-class hands-on SLDC lab was understood	In-class hand-on SLDC lab was useful	Mechanical room SLDC lab was understood	Mechanical room SLDC lab was useful	Mechanical room DDC lab was understood	Mechanical room DDC lab was useful	Instructors encouraged student participation	Instructors were effective	The course content was appropriate	I will use the workbook as a reference	The training added to my knowledge and skills	The training will improve my job performance	My expectations were met	I would recommend course to others	Comment (See next page)
1	Ashley		x	x	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1
2	R.Edge	x	x	x	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
3	SB	x	x	x	5	5	5	5	5	5	5	5	5	4	5	4	5	5	4
4	Ed	x	x	x	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
5	Edward C	x	x	x	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6
6	T. Patrick		x	x	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5
7	J. Richardson	x	x	x	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
8	Bob		x	x	5	5	5	5	5	5	5	5	5	4	5	5	5	5	7
9	Steve	x	x	x	5	5	5	5	5	5	5	5	5	5	5	5	5	5	8
10	No name	x	x	x	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
11	No name	x	x	x	4	4	4	4	4	4	5	5	5	4	4	3	3	3	
12	No name	?	?	?	4	5	4	5	4	5	5	5	5	5	5	5	5	5	2
13	No name	?	?	?	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
14	No name	x	x	x	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3
15	No name		x	x	5	4	4	5	4	5	5	5	5	5	5	5	5	5	
16	No name		x	x	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
17	No name	x	x	x	4	4	4	4	4	4	4	4	4	5	5	4	4	5	
18	No name	x	x	x	4	5	4	5	5	5	5	4	5	5	5	5	5	5	
19	No name			x	4	4	4	4	4	4	5	5	5	5	5	5	5	5	
20	No name	x		x	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
21	No name		x	x	4	4	4	4	4	4	4	5	5	5	4	4	5	5	
22	No name	?	?	?	3	4	3	4	3	4	4	5	4	5	4	4	4	5	
23	No name	?	?	?	4	4	5	5	4	4	4	5	5	5	5	4	4	4	
24	No name	?	?	?	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
	AVERAGE:				4.6	4.7	4.6	4.8	4.6	4.7	4.8	4.9	4.9	4.8	4.8	4.7	4.8	4.8	

Training Course Evaluation Results
(Student Comments)

Comments*
1) I realize the scope of this class was limited and there is only so much that can be adequately covered in the amount of time allowed, troubleshooting is still an area of concern for me.
2) Class was very good and very needed. Thanks.
3) I would like more hands on training.
4) GOOD TRAINING
5) The class is very relevant to the task that we as HVAC Mech. face.
6) Need more mechanical room, hands on.
7) I give the instructors an overall rating of 6. The doughnuts were good. Thanks.
8) Great course.
* Note: A question mark (?) indicates that the portion of the Evaluation form was left blank (where the student was asked to circle the courses that were attended).

Appendix B: Partial Listing of Local Resources

System Integrators

This is a tentative/partial list of System Integrators serving North Carolina, obtained from Circon Systems Corporation:

Padgett Services	Commercial Mechanical Systems, Inc.
http://www.padgettservices.com/index.html Location: Charlotte, NC Contact: Scott Moore Phone: 704.598.9889	http://www.commech.com Contractor Type: Controls, Mechanical, Security Address: 5410 Old Poole Road, Raleigh, NC 27610 Regions Served: NC Contact: Richard Wilkins (President) Phone: 919.431.9411 Fax: 919.431.9899 Email: rwilkins@commech.com

This list was obtained from Echelon's Open Systems Alliance (OSA) website. (Commercial Mechanical Systems, from above list, is also listed at the OSA website)

Chesapeake Controls, Inc.

(http://chesapeakecontrols.com/)
Contractor Type: Controls, Mechanical, Other: Facility Management
Address: 1220 Executive Blvd., Suite 108, Chesapeake, VA 23320
Regions Served: DC, MD, NC, VA
Contact: Rick Evans (Vice President of Sales)
Phone: 704.598.9884
Fax: 757.547.2781
Email: rickevans@chesapeakecontrols.com

Engineered Control Solutions, Inc.

http://www.ecscontrols.net/

Contractor Type: Controls, Energy Services, Other: Facility Management, HVAC Commissioning Services
Address: PO Box 30114; Raleigh, NC 27622
Regions Served: NC, SC, VA
Contact: Jack Connell (President)
Phone: 919.567.0706
Fax: 919.567.0705
Email: jack.connell@ECScontrols.net

CMS Mechanical Services Company

http://www.cmsmechanical.com
Contractor Type: Controls, Mechanical, Security, Energy Services, Other: IT/Communications and Facility Management
Address: 445 West Drive, Melbourne, Fl 32904-1060
Regions Served: FL, GA, MD, NC, SC, VA
Contact: Rick Tom Volmert
Phone: 321.727.2865
Fax: 321.727.2270
Email: tomvolmert@cmsmechanical.com

Facility Robotics, Inc.

http://www.facilityrobotics.com
Contractor Type: Controls, Mechanical, Electrical, Security, Energy Services, Fire Alarm, Other: Enterprise Web Based Solutions
Address: 400 Market Place, Roswell, GA 30076
Regions Served: (all 50 states)
Contact: Lionel Silverman (VP – Bus. Development)
Phone: 770.640.0071 x 106
Fax: 770.640.7224
Email: lsilverman@facilityrobotics.com
Note: Carolinas Division is located in Charlotte
Contact: David Hartman
Phone: 704-525-2374

Acceptable UMCS Front-End Software and LNS Network Tool Suppliers

Acceptable* UMCS Front-End Software Suppliers

Circon (Visual Integrator 3)
Honeywell (EBI or SmmetrE)
Wonderware (Intouch)
Intellution (FIX)
TAC (VISTA)

Acceptable* LNS Network Configuration Tool (Software) Suppliers

Circon (Network Integrator)
Honeywell (CARE 4.0) {Writes LNS, but not doesn't use/read LNS}
Richards Zeta (PerfectHOST for LNS)
Visual Control (VC Network Manager)
Echelon (LonMaker) {TAC uses this tool}
Distech (LonWatcher)
Johnson Controls (MCL Tool) {Not on Echelon Website}

* CERL does not have in-depth/first hand experience with all listed vendors, and has made a judgment based on available information. In addition, the list of vendors is not necessarily complete. A detailed review of the proposed software should be performed prior to selection.

Acceptable DDC Hardware

Application Specific Controllers (ASCs) with LNS Plug-Ins*

Honeywell:
Excel 10 Fan Coil Unit Controller
Excel 10 Hydronic Controller
Excel 10 Constant Volume Air Handling Unit (W7750)
VAVII/SmartVAV Controller

Johnson Controls:
LN Series - Fan Coil Unit Controller
LN Series - Roof Top Controller
LN Series - Heat Pump Controller
LN Series - VAV Box Controller
LN Series – Programmable Controller !?
VMA controller (using HVACPro as plug-in)

Distech:
ECVAV-L VAV Controller
EC-FCU-L Fan Coil Controller
EC-RTU-L Roof Top Unit Controller
EC-UV-L Unit Ventilator Controller
EC-HPU-L Heat Pump Unit Controller
Others

TAC:
Xenta 102 Fan Coil Controller
Xenta 102 VAV Controller
Xenta 110 Dual Zone Controller
Xenta 104 Roof Top Unit Controller
Others

Circon:
UHC-302 VAV Controller
SCC-300-AHC Air Handler Controller
SCC-300-FCC Fan Coil Unit Controller
SCC-300-HPC Heat Pump Unit Controller
SCC-300-RTC Rooftop AC Unit Controller
SCC-300-UVC Unit Ventilator Controller
Others

* CERL does not have in-depth/first hand experience with all listed vendors and generated this list using available information. In addition, the list is not necessarily complete so a review of the availability of a plug-in for a specific controller or the availability of a controller with a plug-in for a specific application should be performed prior to selection.

Miscellaneous ASCs with LNS Plug-ins*

ABB:
N400 Variable Speed Drive
N60030 Variable Speed Drive
N60050 Variable Speed Drive

Veris:
H8920-3 Energy Meter

Belimo:
Various valve and damper actuators

Bremer:
VIVA CoffeeMachine
Others: 57 multi-national / multi-technology companies

Continental Control Systems:
WattNode-FT10 (but not WattNode Plus)

Acutherm:
Therma-Fuser VAV Module

Hubbel:
Various light, temperature and occupancy sensors

* CERL does not have in-depth/first hand experience with all listed vendors and generated this list using available information. In addition, the list is not necessarily complete so a review of the availability of a plug-in for a specific controller or the availability of a controller with a plug-in for a specific application should be performed prior to selection.

O&M Websites (For possible use by O&M staff)

HVAC Controls Data Sheets / Installation Instructions

Johnson Controls "QuickLIT" Product literature. Search feature provided. Includes installation and adjustment instructions.

http://cgproducts.johnsoncontrols.com/

http://hbctechlit.honeywell.com/

Honeywell Controls. Product literature. Search feature provided. Includes installation and adjustment instructions.

http://hbctechlit.honeywell.com/

HVAC O&M Resources

The following websites might help locate answers to O&M problems:

http://www.google.com/

http://tristate.apogee.net/cool/home.asp

http://hvac-talk.com/

http://www.mechanicalminds.net/

http://www.hvacportal.com/index.html

http://www.maintenanceworld.com/index.htm

http://www.hvacmechanic.com/

http://www.eng-tips.com/index.cfm

http://www.taftan.com/thermodynamics/PSYCHART.HTM

http://www.flowmeterdirectory.com/hvac_terminology.html

http://www.maintenanceresources.com/

http://www.eere.energy.gov/femp/operations_maintenance/ (click on "Technologies")

http://www.cirris.com/testing/resistance/wire.html

LonWorks

LonMark International (main website for LonWorks)

http://www.LonMark.org/products/

Inventor of ANSI/EIA 709.1

http://www.echelon.com/support/

Open Systems Alliance (OSA)

http://osa.echelon.com/

LonWorks product

http://www.engenuity.com

Government

CERL Building Energy/Controls

http://www.cecer.army.mil/KD/HVAC/

Corps of Engineers training/purple book (PROSPECT)

http://pdsc.usace.army.mil/

TECHINFO (guidance documents)

http://www.hnd.usace.army.mil/techinfo/

UMCS MCX

http://www.hnd.usace.army.mil/umcs/

Savannah District

http://www.sas.usace.army.mil/eng/EngWeb/hvac.htm

Appendix C: Building Acceptance Checklist

Building Acceptance Checklist Instructions

For a specific project, the Area Office should initiate the Checklist by completing applicable sections and then routing it to the O&M Chief. The chief initials it and routes it to the appropriate FMD Shop Supervisor and/or Work Leader who is responsible for day-to-day progression of the checklist for the specific construction project. The Area Office should be responsible for notifying FMD of upcoming checklist items that require FMD staff participation.

1. Design Phase

- Perform an operability review of the system design and spec
- Things to check for in design/spec: Equipment accessibility, Performance/test requirements, Training requirements are sufficient, Training at end of warranty period, Provide input to the training requirements contained in the job spec (make sure they meet your needs including the content of the training and number of training hours). Consider combining training with system testing.
- Make sure there are performance/test requirements in the spec
- Written comments: Sequentially number each comment and refer to specific page and paragraph number and/or drawing sheet number. Include your name and date of the review. Keep a copy and give one to your supervisor (or other designated person).

2. Construction Phase

- Follow project execution so that training dates do not fall through the cracks.
- Take a copy of the Contract training requirements to the training.
- Include FMD staff member name/phone on FMD generated punch lists.
- Check sequence of operation to verify inputs/outputs/control

Building Acceptance Checklist

Building / Project number: _____

Construction Inspector name/phone/email: _____

FMD shop POC (supv or work leader): _____

Other FMD staff involved with project: _____

Design Phase:

1. Operability review of the system design and spec complete
FMD Reviewer name & date: _____
Written comments submitted to: _____

(Short list of things to check for in design/spec: Equipment accessibility, Performance/test requirements, Training requirements are sufficient, Training at end of warranty period)

Construction Phase:

5. System test/acceptance/inspection preparation
Tentative dates: _____ (provided to FMD by Govt. Construction Inspector)
Actual dates: _____ (provided to FMD by Govt. Construction Inspector)
FMD notified of actual date on: _____ (by Govt. Construction Inspector)

6. System test/acceptance/inspection attendance
FMD Reviewer name & date: _____
Posted Instructions & Maintenance Manuals provided: yes / no
Contractor demonstrated control sequence of operation: yes / no
FMD staff member generated punch list: yes / no
FMD punch list provided to Corps Construction Inspector: yes / no
If not who? _____
FMD punch list copy provided to supervisor: yes / no

7. Training preparation
Copy of Contract training requirements provided to FMD: yes / no
Tentative training dates: _____ (provided to FMD by Govt. Construction Inspector)
Actual training dates: _____ (provided to FMD by Govt. Construction Inspector)
FMD notified of actual date on: _____ (by Govt. Construction Inspector)

8. Training attendance.
FMD staff who attended training: _____
Contractor met Contract specification training requirements: yes / no

Appendix D: Results of O&M Management Plan and IDG Review

Fort Bragg IDG Recommendations

http://www.bragg.army.mil/pwbc/idg/html/chapter3/fr_ch3-2.htm

3.2.8 Mechanical Systems

A. Consider renaming "Maintenance Access." Retain existing text and add (possibly as new paragraphs):

1. All equipment shall be installed in accordance with the manufacturer's clearance and access requirements. Access ports/doors shall be provided for HVAC duct mounted equipment that may require maintenance inspection or access, particularly air flow measurement stations. Waterside pressure, temperature and flow test and measurement ports, gages, or devices shall be provided for testing, adjusting and balancing (TAB) as specified by SMACNA, NEBB, or AABC balancing agencies.
2. Mechanical rooms shall include lift points for hoisting of equipment. Lift points shall be rated for the anticipated load application(s).
3. Where equipment requiring maintenance access is installed more than 15 ft above the floor catwalks shall be provided. This includes VAV boxes.
4. Equipment requiring maintenance access shall not be installed above dry wall ceilings, especially VAV boxes and fan coil units.
5. Pump motors greater than 5 hp shall be mounted at floor level.

F. Fan coil units or constant volume single zone or multi-zone AHUs shall be installed. Variable air volume HVAC systems shall be installed on an exception basis only upon approval by the DPW Director. When VAV systems are provided they shall be designed and installed in accordance with the following requirements:

1. The design shall avoid the use of return and relief air fans because of the added maintenance requirements and complexity of the controls.
2. VAV system air handlers shall not contain DX coils.
3. Fan-powered VAV boxes shall be installed on an exception basis only upon approval by the DPW Director. When a fan-powered box is supplied, drawings/instructions shall be posted in the mechanical room that contain a list of each VAV box, it's identifying number, physical location (room number), and the part number and size of the VAV box filter.

4. Locate VAV boxes in unoccupied spaces (closets, hallways, conference rooms, etc.) if maintenance access requirements can be adhered to. Co-locate VAV boxes where possible.
5. Locate VAV box controls and controlled devices (dampers/valves) no more than 10 ft above the floor such that they can be accessed, for maintenance, using an 8-ft step ladder.
6. Mark the drop-ceiling tile or grid at the location of each VAV box controller. If fan powered boxes are used, mark the tile/grid at the location of the filter.
7. VAV box controllers shall have service tool (i.e., laptop) access jacks at the thermostat.
8. When the VAV box controllers are networked together via a communications cable such that any controller is accessible from a common/single access point using a service tool (i.e., laptop), drawings/instructions shall be posted in the mechanical room showing a list that cross references the VAV box with its address/channel number such that when a service tool (laptop, etc.) is used to access the VAV box over a distributed network the physical location of the box (i.e., room number) is evident to the user of the service tool.
9. Drawings/instructions shall be posted in the mechanical room that show the location of each VAV box (floor plan ductwork layout) along with an identifier (for each VAV box) that is consistent with (or cross referenced to) the identifiers shown on all other drawings.
10. A copy of all posted drawings/instructions shall be supplied in a three ring binder. The binder shall be supplemented with other O&M information/data deemed useful by the contractor.

H. Retain the existing first two sentences. Replace the third and fourth sentences with (and consider making this a new lettered paragraph): DDC controls shall be based on LonWorks Technology designed and installed in accordance with UFGS-15951, which is based on ANSI/EIA 709, EIA-852, and the LonMark Interoperability Guidelines in support of base-wide multi-vendor interoperability. Gateways (protocol translators) shall be avoided, but may be provided on an exception basis only as specified in UFGS-15951. BAS technologies that lead to proprietary sole-source procurement for system expansions are not acceptable. An exception to UFGS-15951 is that programmable DDC controllers shall not be used. Instead, only application specific controllers (ASC) are permitted. Where an application specific controller is deemed unsuitable by the contractor (due to the complexity of the application), the contractor shall obtain Contracting Officer (or CO Representative) approval for use of a programmable controller. Contractor's are encouraged to propose an alternate (less complex) control sequence that will result in the use of an ASC in lieu of a programmable controller.

H. After the existing second sentence add: Thermostats in office spaces shall be located near doorways, light switches, on columns, or other carefully selected locations where modular furniture or other tall equipment (present and future) will be least likely to obscure the thermostat.

H2. (New lettered paragraph) DDC control system installation shall be coordinated with the Fort Bragg UMCS System Integrator culminating, as specified in UFGS-15951,

in the submission of an LNS database for the project and an LNS plug-in for each installed application specific controller/device.

I. Chillers shall include as a minimum the following features:
Retain existing requirements and add:
6. Permanently installed ladder providing access to the top of the chiller

Additional IDG Suggestions (That Do Not Fit into the Pre-Existing Categories)

- *Shutoff Valves.* On water mains, full-port ball values shall be used, not gate valves.
- *Labeling.* All devices and panels shall be labeled. Labeling shall be consistent with the as-built drawings.
- *Safety Codes.* All safety codes shall be observed and adhered to.
- *Building Acceptance and Acceptance Test Schedule.* FMD shall be included in the contractors building acceptance and acceptance test schedule.
- *Current Equipment.* Equipment/products shall be current production items available from the manufacturer as stocked items. No used or outdated equipment shall be installed.

Fort Bragg DDC O&M Management Plan and IDG Review Meeting Attendance

Name	Organization	Phone
Cagle, Bob	USACE, Savannah CD-PS	910-432-8121
Craig, Gary	DPW Operations	396-6368
Crisco, Edward W.	DPWE	396-2030
Dunning, Steve	DPW	396-3013
Ellison, Mike	DOIM	396-4119
Ford, Robert	USACE CD-BRC	396-9977
Gehle, Jim	USACE SAS-CD-BR	396-1211
Gray, Kenneth	USACE SAS-CD-BR	396-1211 X240
Hudson, Judi	DPW	432-6336
Hughes, Lucie	USACE, Savannah	912-652-5645
Jackson, Calep Ray	DPW-QSI-I	396-3013
Lyons, Jason	DPW-FMD	432-6010
McDonald, Ronald	DPW, QSI	396-3013
Meekins, Marcia	COE	
Morgan, Stephanie	USACE CD-BRC	396-9977
Nesbit, Larry	DOIM	396-4421
Patrick, Tom	DPW-FMP	396-2030
Paulson, Eric	USACE SAS-CD-BR	396-1211
Pierce, Wilhelmina	USACE SAS-CD-BRC	396-9977
Richardson, James	DPW, QSI-I	396-3013
Rose, John	DPW-CMD	396-1211 X245
Santos, Rafael	DPW, QSI	960-1054
Smith, Frank	DPW FMD	396-6145
Strain, Kirk	DOIM	396-2714
Taylor, David	DPW	396-6033
Tucker, Michael S.	USACE SAS-CD-PSS	432-8121
Watters, Jay	DPW/CMD	396-4243
Williams, Denise	USACE, Savannah District	912-652-5355

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Training and Technical Assistance

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5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
David M. Schwenk, Joseph Bush, and David M. Underwood

5d. PROJECT NUMBER
MIPR

5e. TASK NUMBER
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U.S. Army Engineer Research and Development Center (ERDC)
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Commander, Fort Bragg
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14. ABSTRACT

Fort Bragg DPW Facility Maintenance Division Chief requested the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) to provide the installation with site-specific heating, ventilating, and air conditioning (HVAC) systems and controls training and technical assistance. CERL and installation Directorate of Public Works (DPW) management and maintenance staff worked together to identify maintenance issues, training needs, and required resources. This work determined that installation personnel could benefit from three training courses, which CERL developed and provided: (1) Introduction to HVAC and Control Systems Operations and Maintenance (O&M), (2) Advanced HVAC Control Systems O&M I, and (3) Advanced HVAC Control Systems O&M II. CERL also worked with Fort Bragg to identify a direct digital control (DDC) O&M management plan and provided recommendations on how to resolve other ongoing O&M problems.

15. SUBJECT TERMS
Ft. Bragg, NC
HVAC
operation & maintenance
controls
heating systems
energy conservation

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a. REPORT	b. ABSTRACT	c. THIS PAGE			David M. Schwenk
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